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(54) Title of Invention: **EXPOSURE APPARATUS**

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## SPECIFICATION

### TITLE OF THE INVENTION

Exposure apparatus

### CLAIMS

1. An exposure apparatus that performs a pattern exposure by irradiating light from an exposure illumination system upon a member to be processed, which is disposed on a mounting platform, through a mask and a lens, wherein

exposure is performed by interposing a liquid, which has a refractive index substantially equal to or slightly less than that of said lens, between said lens and the member to be processed or between said lens and said mask.

2. An exposure apparatus as recited in Claim 1, wherein

water is used as said liquid.

3. An exposure apparatus that performs a pattern exposure by irradiating light from an exposure illumination system upon a member to be processed, which is disposed on a mounting platform, through a mask, wherein

said mounting platform comprises a heating apparatus for setting the member to be processed to a prescribed temperature; and

pattern exposure is performed at said prescribed temperature.

4. An exposure apparatus as recited in Claim 3, wherein

said mounting platform uses a vacuum chuck system, which is releasable from said member to be processed, and comprises:

a plate chuck that has said heating apparatus; and

a movable stage that is attached to the plate chuck.

5. An exposure apparatus as recited in Claim 3 or Claim 4, wherein

a heater or an apparatus that circulates high temperature liquid is used as said heating apparatus.

6. An exposure apparatus as recited in any one claim of Claim 3 through Claim 5, wherein

said prescribed temperature is approximately 100° C.

## DETAILED EXPLANATION OF THE INVENTION

### [FIELD OF THE INVENTION]

The present invention relates to an exposure apparatus.

### [RELATED ART]

In recent years, the increasing fineness of VLSI and LSI devices has resulted in the need to greatly increase resolution in exposure apparatuses as well, and to greatly improve dimensional controllability. Furthermore, there is also a need to improve the yield of LSI devices.

Resolution  $R$  of an exposure apparatus is expressed by the following relationship:

$$R \propto \lambda / \text{N.A.} \quad (1)$$

Therein,  $\lambda$  is the exposure wavelength and N.A. is the numerical aperture of the optical system. In addition, the numerical aperture N.A. of the optical system is expressed by the following relationship:

$$\text{N.A.} = n \cdot \sin \theta \quad (2)$$

Therein,  $n$  is the refractive index of the medium on the object point side of the objective lens, and  $\theta$  is the aperture half-angle.

Accordingly, to increase the resolution  $R$ , either: (a)  $\lambda$  should be decreased, or (b) N.A. should be increased, i.e., increase  $\theta$  or  $n$ .

Here, let us consider increasing the resolution  $R$  by increasing  $n$  and increasing N.A.

Moreover, it is conceivable to improve the resolution, dimensional controllability, and the like by focusing on the resist.

Namely, a wafer in a normal exposure apparatus is maintained at a temperature the same as the room temperature. However, even at this temperature, it is known that the photosensitive group in an  $\text{Ag}_2\text{Se}/\text{Ge}_x\text{Se}_{1-x}$  system resist (negative resist) as well as in the system of the normally used positive resist diffuses in the resist; in addition, the contrast enhancement effect of the former resist as well as the reduced standing wave effect of the latter resist are known. Furthermore, the enhancement of contrast by the diffusion of Ag in an  $\text{Ag}_2\text{Se}/\text{Ge}_x\text{Se}_{1-x}$  system is described in "Ge-Se based resist systems for submicron VLSI application," R.G. Vodinsky and L.T. Kemever, SPIE Vol. 394 (1983).

First, addressing the former  $\text{Ag}_2\text{Se}/\text{Ge}_x\text{Se}_{1-x}$  system resist, when a mask 1 (wherein a pattern 3 is formed on a mask substrate 2) is irradiated with a light from an exposure illumination system, as shown in FIG. 2(a), the photosensitive group of an  $\text{Ag}_2\text{Se}/\text{Ge}_x\text{Se}_{1-x}$  system resist 5

(negative resist) on the front surface of the wafer 4 diffuses from the circumference to the portion 5a (portion indicated by diagonal lines) that was exposed at room temperature, as shown by the arrows, and thereby become insoluble in the developing solution. FIG. 2(b) shows the normal light intensity with respect to the position  $x$  of the resist that was exposed at room temperature; in addition, A in FIG. 2(c) shows the corresponding reactivity of the resist and depicts the rise characteristic. With this characteristic, it can be seen that the level difference between the high and low portions is not that great and therefore the resolution is insufficient. Accordingly, to improve the resolution, the degree of diffusion of the photosensitive group to the exposure portion 5a should be increased. The problem is how to take such measures.

In addition, with the latter positive resist system, a positive resist 6 on the front surface of the wafer 4 is exposed in a wavy manner at the interface portion due to the standing wave effect, and the resist that absorbed the light is decomposed at the portions indicated by the reference symbol 7. However, even at room temperature, although the diffusion of the photosensitive group, as discussed earlier, reduces the standing wave effect, dimensional controllability is still insufficient. Accordingly, to improve dimensional controllability, the standing wave effect must be reduced even further, but there is a problem in how to accomplish that end.

Thus, there is a problem in how to improve the resolution and dimensional controllability of the resist.

Based on the above, the improvement of the resolution  $R$  of the exposure apparatus as well as the improvement of the resolution and dimensional controllability of the resist are extremely important issues from the viewpoint of improving the yield of LSI devices of which are becoming increasingly finer.

## **[OBJECTS OF THE INVENTION]**

It is an object of the present invention to provide an exposure apparatus that improves resolution and dimensional controllability, and thereby improves the yield of a member to be processed.

This and other objects and novel features of the present invention will become apparent from the description of the present specification and the appended drawings.

## **[SUMMARY OF THE INVENTION]**

The following briefly explains an overview of a representative embodiment of the invention disclosed in the present application.

Namely, in a reduction projection exposure apparatus, an exposure is performed by interposing a liquid, e.g., water, which has a refractive index somewhat less than that of a lens of a reduction lens system, between a wafer surface and the lens, and higher resolution is thereby obtained and the yield of the wafer, which is the member to be processed, is improved.

In addition, in an exposure apparatus, a heating apparatus for the purpose of heating the wafer to a prescribed temperature is built into a mounting platform, whereon the wafer to be pattern exposed is disposed, and a sufficient diffusion of the photosensitive group is achieved in the resist formed on the front surface of the wafer while performing the exposure, which improves the resolution and dimensional controllability of the resist, thereby improving the yield of the wafer, which is the member to be processed.

#### [FIRST EMBODIMENT]

FIG. 1 shows one embodiment of the exposure apparatus according to the present invention, and particularly shows the case for a reduction projection exposure apparatus. Here, the following explains the present invention as exemplified by a case wherein the member to be processed is adapted to a wafer.

Reference symbol 11 is a mercury lamp and reference symbol 12 is a condenser lens, both of which constitute an exposure illumination system 13. The light from the mercury lamp 11 is irradiated upon a reticle 14, which functions as a mask, through the condenser lens 12, and then enters one lens 15a of a reduction lens system 15. Reference symbol 16 is a tubular member, and an antireflective film is deposited on the inner surface side thereof. A liquid, herein water 18, that has a refractive index slightly less than that of another lens 15b of the reduction lens system 15 is interposed between the front surface of the wafer 17 and the lens 15b. Accordingly, the light emerging from the other lens 15b of the reduction lens system 15 reaches the wafer 17 through the water 18. Furthermore, the resist on the front surface of the wafer 17 is pattern exposed. Here, because the lens 15b and the wafer 17 are extremely proximate to one another in order to perform the exposure with the space between the lens 15b and the wafer 17 immersed with the water 18, the entire wafer 17 may be exposed by a step-and-repeat system after immersing the entire front surface of the wafer 17 in water in advance; alternatively, prior to exposing each of the locations on the wafer 17 that are to be successively scanned and exposed, an immersion exposure is performed while supplying water onto the wafer 17 at the portion about to be exposed (if exposing four chips at a time, the corresponding four chip portions). Reference symbol 19 is a chuck plate (wafer chuck), whereon the wafer 17 is disposed, that holds the wafer 17 by suction at a prescribed position using a vacuum chuck system. The chuck plate 19 is attached to an XY motion stage 20. The XY motion stage 20 is constituted so that it can move freely in the horizontal directions (the X and Y directions), and the wafer 17 can be aligned with the prescribed position to be exposed by moving the XY motion stage 20.

In the exposure apparatus constituted as described above, the refractive index  $n$  in equation (2) is increased in order to increase the resolution. Based on the principle of liquid immersion, the refractive index  $n$  of the medium should be substantially equal to or slightly less than the refractive index of the lens 15b. Accordingly, the water 18 is used as the liquid that has a refractive index substantially equal to or slightly less than that of the lens 15b. The water 18 has a refractive index (4/3) that is greater than that of air. By interposing the water 18 between the lens 15b and the wafer 17, it is possible to increase the numerical aperture N.A. of the optical system, i.e., the reduction lens system 15, and to markedly increase the resolution in equation (1). Furthermore, it is also possible to increase the yield of the wafer, which is the member to be processed, i.e., the yield of the LSI devices.

## [SECOND EMBODIMENT]

The following explains the second embodiment of the present invention, referencing FIG. 1.

1. The chuck plate 19 comprises a built-in heating apparatus for heating the wafer 17, and, accordingly, the resist on the front surface thereof to a prescribed temperature, e.g., approximately 100° C, without immersion in the water 18 in FIG. 1. The prescribed temperature is selected in accordance with the type of resist. Normally, a temperature in the vicinity of 100° C is selected.

Furthermore, although not shown herein, a heater (e.g., a resistance heater and the like), an apparatus to circulate the high temperature liquid, and the like are used as the heating apparatus, which is constituted so as to maintain the prescribed temperature during the exposure. A constitution is also acceptable wherein fixed control is performed in order to maintain the prescribed temperature.

The wafer 17 is exposed by the apparatus shown in FIG. 1 at a temperature, herein approximately 100° C, that is higher than room temperature.

First, if the resist is an  $\text{Ag}_2\text{Se}/\text{Ge}_x\text{Se}_{1-x}$  system resist, then exposure is performed at a high temperature (approximately 100° C), and it is therefore possible to further promote diffusion of the photosensitive group in the resist, and the level difference in the reactivity of the resist at the exposure portion on the front surface of the wafer 17 is extremely large between the exposed portion and the unexposed portion, as depicted by B in FIG. 2(c). This shows that the photosensitive group was sufficiently diffused in the exposure portion 5a. Thus, by increasing the contrast enhancement effect, it is possible to further increase the resolution, which thereby increases the yield of the wafer, i.e., the LSI devices.

The following explains a case wherein a positive resist is used as the resist. In this case, the standing wave effect is notable, as discussed earlier, and is markedly reduced by performing the exposure at high temperature (approximately 100° C) with the present invention. In other words, performing the exposure at high temperature can markedly promote the diffusion of both the decomposed and undecomposed portions of the photosensitive group in the resist; moreover, the exposure can be performed while performing such diffusion, and an indistinct state therefore arises wherein the decomposed and undecomposed portions of the photosensitive group are mixed together at an exposure portion 6a in FIG. 3. As a result, the interface surface at the interface portion between the exposed and unexposed portions of the resist 6, as shown by the dotted lines C and D, become linear, and it is therefore possible to markedly reduce the standing wave effect. Accordingly, it is possible to improve the dimensional controllability of the resist pattern as well as the device pattern, and it is thereby possible to improve the yield of the wafer, which serves as the member to be processed, i.e., the LSI devices.

## [EFFECTS OF THE INVENTION]

(1) By increasing the numerical aperture N.A. of the optical system using the principle of liquid immersion, high resolution is obtained and it is thereby possible to improve the yield of the member to be processed (e.g., the LSI devices on the wafer).

(2) By performing processes at a high temperature (either performing exposure at a high temperature or performing a high temperature process after exposure), it is possible to markedly promote the diffusion of the photosensitive group in the resist and to increase the contrast enhancement effect; accordingly, it is possible to markedly increase resolution and thereby to improve the yield of the member to be processed (e.g., the LSI devices on the wafer).

(3) By performing processes at high temperature (either performing exposure at high temperature or performing a high temperature process after exposure), it is possible to markedly promote the diffusion of the photosensitive group in the resist and to markedly decrease the standing wave effect; accordingly, it is possible to markedly improve dimensional controllability and thereby to improve the yield of the member to be processed (e.g., the LSI devices on the wafer).

The above specifically explained the present invention, which was created by the present inventors, based on the embodiments, but the present invention is not limited thereto, and it is understood that variations and modifications may be effected without departing from the spirit and scope of the invention. For example, the first embodiment is a case wherein the liquid is interposed between the lens 15b and the wafer 17, but may be interposed between the lens 15a and the reticle 14, which serves as the mask. In FIG. 1, the liquid should be filled in a tubular member 16. With an exposure apparatus wherein a member like the tubular member 16 is not provided and disposed, a member similar to the tubular member 16 may be appropriately used.

In addition, with the second embodiment, the exposure is performed at high temperature, but the entire wafer 17 may be heat treated at a high temperature (at a prescribed temperature) in a second by the heating apparatus built into the chuck plate 19, or may be processed at high temperature by a heating apparatus provided separately from the exposure apparatus. In these cases as well, the same operational effects discussed earlier are obtained. However, the processes of the second embodiment are shortened, which improves throughput.

Furthermore, the present invention may use an exposure apparatus, e.g., a reduction projection exposure apparatus, wherein the first embodiment and the second embodiment are used in combination, i.e., the liquid immersion of the first embodiment and the chuck plate 19 built into the heating apparatus of the second embodiment are used in combination. In this case, a higher resolution is obtained, particularly in the case of a negative resist; in addition, it is also possible to improve resolution and dimensional controllability in the case of a positive resist.

#### **[INDUSTRIAL FIELD OF APPLICATION]**

The above principally explained a case wherein the invention, which was created by the present inventors, was adapted to the pattern exposure of a wafer that serves as the member to be processed, which is the field of use underlying the present invention, but the present invention is not limited thereto and can be adapted to, for example, full field exposure for forming the pattern

of, for example, a reticle. The present invention can be adapted to a case wherein at least the exposure of a member to be processed is required.

## **BRIEF DESCRIPTION OF THE DRAWINGS**

FIG. 1 is a schematic block diagram that shows one embodiment of an exposure apparatus according to the present invention.

FIG. 2(a) – (c) and FIG. 3 are for the purpose of explaining the present invention.

11	Mercury lamp
12	Condenser lens
13	Exposure illumination system
14	Reticle
15	Reduction lens system
15a, 15b	Lenses
16	Tubular member
17	Wafer
18	Water
19	Chuck plate
20	XY motion stage